The size and orientation of the spikes produced by a pacemaker are often used by clinicians as an index of the pacemaker's function. Following implantation, the pacemaker spikes ordinarily remain constant in size; alterations suggest electrical or mechanical malfunction. We describe a patient in whom giant spikes from a pacemaker were recorded on a digital electrocardiograph shortly after implantation. An electrocardiogram taken the following day, using an analog machine, showed marked diminution in the pacemaker spike. Because of a different type of signal processing, digital electrocardiographs show much larger spikes from pacemakers than do analog machines.

*From the Division of Cardiology, Veterans Administration Medical Center, and the University of Maryland School of Medicine, Baltimore.
†Associate Professor of Medicine.

The electrical impulse produced by a pacemaker appears on the electrocardiogram as a high-frequency deflection (the pacemaker artifact), the size of which is related to the location and orientation of the electrodes. Unipolar pacemakers characteristically produce a larger deflection than bipolar units, presumably because of the large dipole between the intracardiac cathode and the anode. Following implantation, a pacemaker's spikes ordinarily remain constant in size; alterations suggest the possibility of electrical or mechanical malfunction. In the present report, we describe a patient in whom giant spikes from a pacemaker were recorded on a digital electrocardiograph shortly after implantation. A subsequent ECG, taken on the following day using an analog machine, showed a marked diminution in the pacemaker artifact.

**Case Report**

A 47-year-old man was referred for evaluation because of fatigue, lightheadedness, and occasional syncope. Electrocardiograms revealed type-1 second-degree atrioventricular block, and 24-hour ambulatory recordings showed occasional 3:1 atrioventricular block with ventricular rates as low as 20 beats per minute (and a narrow QRS complex). On Jan 28, 1983, a permanent DDD pulse generator (Medtronic Versatrac 7000A) was implanted and connected to unipolar leads in the right atrium (Medtronic 69916-53) and apex of the right ventricle (6971-58), respectively. An ECG using a digital

![Image of electrocardiogram](image-url)
electrocardiograph (Hewlett-Packard 4700 Pagewriter) revealed normal P-wave sensing and ventricular capture associated with giant pacemaker artifacts (Fig 1A). A chest x-ray film showed the leads to be placed appropriately. Another ECG taken the following day, using an analog machine, showed marked diminution of the pacemaker spikes (Fig 1B). Continuous electrocardiographic monitoring in the coronary care unit over the next several days revealed normal function of the pacemaker, and the patient was discharged from the hospital. He has done well over a several-month follow-up period, and ECGs have shown normal function of the pacemaker. The size of the pacemaker spikes has continued to vary (independent of the pacing mode) according to whether a digital or analog machine is used.

**DISCUSSION**

Change in the size of pacemaker artifacts has been described as a manifestation of defective insulation, partial fracture of a lead, a short circuit between electrodes, electrode migration, or generator malfunction and may be a sign of impending failure of the pacemaker.**1** Accordingly, it is of the utmost importance that any change in the size or orientation of the pacemaker spike be promptly investigated. In the present report, we describe giant spikes from a pacemaker which were recorded on a digital electrocardiograph. This finding is of potential clinical importance because it may falsely create the impression of malfunction of the pacemaker, and it may also mask early signs of failure of the pacemaker by obscuring true alterations that occur in the size of the pacemaker spike.

The application of digital signal processing to electrocardiography has provided several major benefits.**1,2** Digital electrocardiographic tracings are of exceptional clarity, and selected formats for different clinical tests can be recorded on a standard 8½ × 11-inch page. Exact lead annotation, lead switching marks, frequency changes, and other relevant notations are written on every record; however, as illustrated in the present report, digital signal processing presents the spike of the pacemaker with a larger amplitude relative to that of a conventional electrocardiograph. Other problems with recording pacemaker spikes on digital machines have also been reported.**3** In fact, pacemaker artifacts can attain amplitudes which are 100 times greater than R waves at the body surface. As they are of very short duration, their frequency content also exceeds that of normal ECGs by several orders of magnitude. To accurately view pacemaker wave forms, an oscilloscope with a frequency bandwidth of 100 kHz and an input range of 1 V is typically used. Comparing these numbers with the specifications for standard electrocardiographs of 200-Hz bandwidth and 40-mV input range, it is clear that all electrocardiographs will distort the pacemaker wave form.

In conclusion, we describe a patient with variation in the size of the pacemaker artifact due to the use of two different types of electrocardiographic machines. The amplitude of the pacemaker spike as presented by an electrocardiograph is not a true representation of the electrical event. In addition, variation in the size of pacemaker artifact is initially dependent upon when the electrocardiograph samples the spike and then is further limited by inappropriate frequency bandwidth, voltage input range, and slew rate response (if using an analog machine).

Furthermore, most of the digital circuits and programs were not developed to handle the large rate of change in voltage occurring during the pacemaker artifact, so that overflow occurs. Thus, we recommend that digital electrocardiographs not be used to assess the direction or amplitude of the spikes from a pacemaker because of the large amount of signal distortion that may occur.

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**Transplant Paradoxical Renal Vasocostriction following Cardiac Operation**

**Treatment with Volume Depletion**

Mark E. Heinsohn, M.D.; Andrew E. Epstein, M.D.; Richard E. Katholi, M.D.

Following cardiac operation complicated by inferior myocardial injury, a patient developed normal cardiac output congestive heart failure associated with severe renal vasoconstriction, oliguria and azotemia. The patient's renal dysfunction responded to volume depletion with hemofiltration. These paradoxical renal responses to volume changes may be caused by transiently altered cardiac volume receptor thresholds or afferent signals resulting in cardiorenal dysfunction.

The kidney plays an important role in the maintenance of vascular volume. The normal renal response to intravascular volume expansion is a natriuresis; the normal

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*From the Department of Medicine, University of Alabama in Birmingham, Birmingham, Alabama. Reprint requests: Dr. Katholi, 315 Zeigler Building, University of Alabama in Birmingham, Birmingham 35294*